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Trade synchronization in the World Trade Web

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Abstract. In March 2008, the bankruptcy of Lehman Brothers marked for many the beginning of the global crisis. In an increasingly globalized world, the financial crisis spread relentlessly. Recent theories of financial fragility link globalization with economic cycles, i.e. when local crises coincide with bad credit regulation and failures in international monetary arrangements. The globalization process in recent years has been accelerated due to to the increase of international trade. Here we analyze how economic cycles can spread worldwide over the global trade network (WTW). We use the WTW network structure to simulate a network of Integrate-and-Fire oscillators for two different years, 1980 and 2000. The results reinforce the idea that globalization accelerates the global synchronization process.

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1. Introduction

The study of financial crises has always attracted a fair amount of interest, but we still know very little about them. Minsky [1, 2] defined financial crises as a natural consequence of changes in the economic cycle and the fragility of the structure of debt. In a capitalist economy the financial system swings between robustness and fragility and does not rely upon exogenous shocks to generate business cycles of varying severity. The crisis is triggered when concur falls in economic activity, poor management of bank credit and systemic liquidity requirements.

According to this definition, a global crisis would be highly unusual, and will only occur when economic cycles of all economies are synchronized. However, in March 2008 the bankruptcy of Lehman Brothers spread the northamerican financial crisis relentlessly world wide. The magnitude of this financial crisis is hard to explain and we will sustain our work on theories that point to a possible relationship between the globalization process and the synchronization of economic cycles.

Deardorff [3] defines globalization as "*the increasing world-wide integration of markets for goods, services and capital*", stressing the idea that globalization is affecting the world as a whole. Since mid-1980s global trade and financial flows have been increased and have appeared new emergent economies. Free trade and increased financial flows can set the channels to spill shocks world wide. Kose *et al.* [4] have analyzed the evolution of business cycles over the globalization period 1985-2005 finding some convergence of business cycle fluctuations among industrial economies and among emerging market economies. Instead, they find little changes in the degree of international synchronization.

Here we analyze how the effects of globalization can affect the ability of synchronization of business cycles, focusing this study on the effects of trade openness. To this end, we use the network of international trade (WTW) [5, 6] where we will represent each country with an Integrate-and-Fire oscillator [7]. We have chosen two snapshots of this network, one for the pre-globalization period (1980) and another belonging to the globalization period (2000). In an increasingly globalized world, we can expect that more tightly coupled countries synchronize quickly.

In next section we define the network of Integrate-and-Fire (IF) oscillators. In section 3 we present the results of our analysis.

2. Integrate-and-Fire network

We first present the WTW network and we overview some basic notation. WTW represents the international transactions among countries as a network. The network is formed by N nodes, one for each country, and L links that correspond to trade flows. Each link has an associated weight w_{ij} that represents the trade between two countries i and j. Thus, the link w_{ij} is the exports of node i to node j, and w_{ji} is the imports of i from j.

For each node i we can calculate the in-strength $s_i^{\text{in}} = \sum_j w_{ji}$, equivalent to the total imports of a country, and the out-strength $s_i^{\text{out}} = \sum_j w_{ij}$, which accounts for its total exports.

To model the economic cycle of each country we associate an oscillator to every node of the network. The synchronization of these oscillators is performed through the commercial channels represented by the links of the network. In this article we use the simple Mirollo and Strogatz IF oscillators model [7]. In this model each oscillator is characterized by a monotonic increasing state variable $x \in [0, 1]$ that evolves according to

$$x = f(\phi) = \frac{1}{b} \ln(1 + [e^b - 1]\phi)\,, \tag{1}$$

where $\phi \in [0, 1]$ is a phase variable proportional to time that satisfies $f(0) = 0$ and $f(1) = 1$, and b is the dissipation parameter that measures the extent to which x is concave down. We can calculate ϕ using the inverse function

$$\phi = g(x) = \frac{e^{bx} - 1}{e^b - 1}\,. \tag{2}$$

When the variable x attains the threshold $x = 1$ it is said to fire, and it is instantly reset to zero, after which the cycle repeats. Now let us assume that a node i of our network of oscillators fires. This node, in turn, transmits to all its neighbors j an excitation signal of magnitude ε_{ij}, thus leaving the variable state $x_j^+ = x_j + \varepsilon_{ij}$. If $x_j^+ \geqslant 1$, oscillator j is also reset and propagates the fire signal to its neighbors, thus generating cascades of fires.

WTW presents a large diversity in the economic weight of countries and their trade flow. It is reasonable to think that a shock in a small country is not spread to a large country with the same intensity than vice versa. And regardless of country size, the volume of transactions appears to be a factor of the ability of trade channel to synchronize the cycles of two economies. To reflect this dependence we define the excitation signal of a node i to its neighbors j as

$$\varepsilon_{ij} = \frac{w_{ij}}{s_j^{\text{out}}}\,. \tag{3}$$

3. Results

To perform our analysis we construct two weighted and directed networks, for 1980 and 2000, with values of N of 160 and 185, respectively. We create

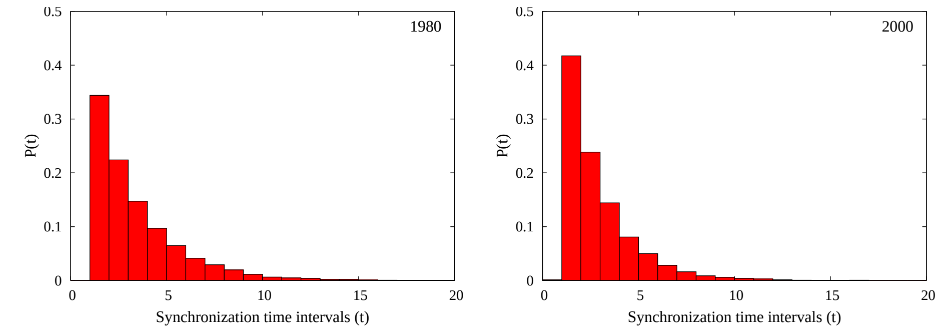

Figure 1: Synchronization time distribution of the WTW network in 1980 (right) and 2000 (left). Bars represent intervals of one cycle.

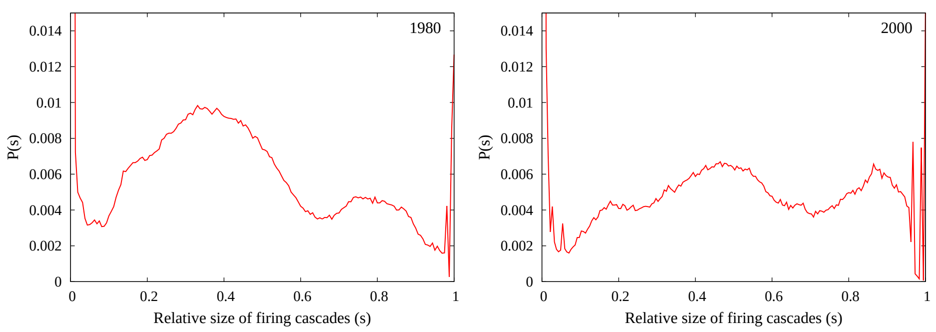

Figure 2: Rate of oscillators firing in cascade respect the system size and its probability distribution for both 1980 and 2000 networks.

an oscillator per country with random initial state. The system evolves as governed by (2.1) and (2.2), with $b = 3$ and ε as it is described in (3). We run 10^4 times the computer simulation of this system until it is perfectly synchronized. Here we present the results that we have found.

First, we examine the time needed to fully synchronize such networks. Figure 1 shows how the trade network in 2000 synchronizes faster than in 1980. About 7% more cases synchronize with a time between 1 and 2 cycles. This fact is directly attributable to the increase in world trade.

In Figure 2 we can see the size of the different cascades of firings before the system perfectly synchronizes. In 1980 in most cases the dimension of cascades is between 25% and 50% of network size. In contrast, in 2000 the cascades present a most homogeneous distribution of sizes. This behavior describes a very regional economy in 1980 compared to 2000, where the trade is global.

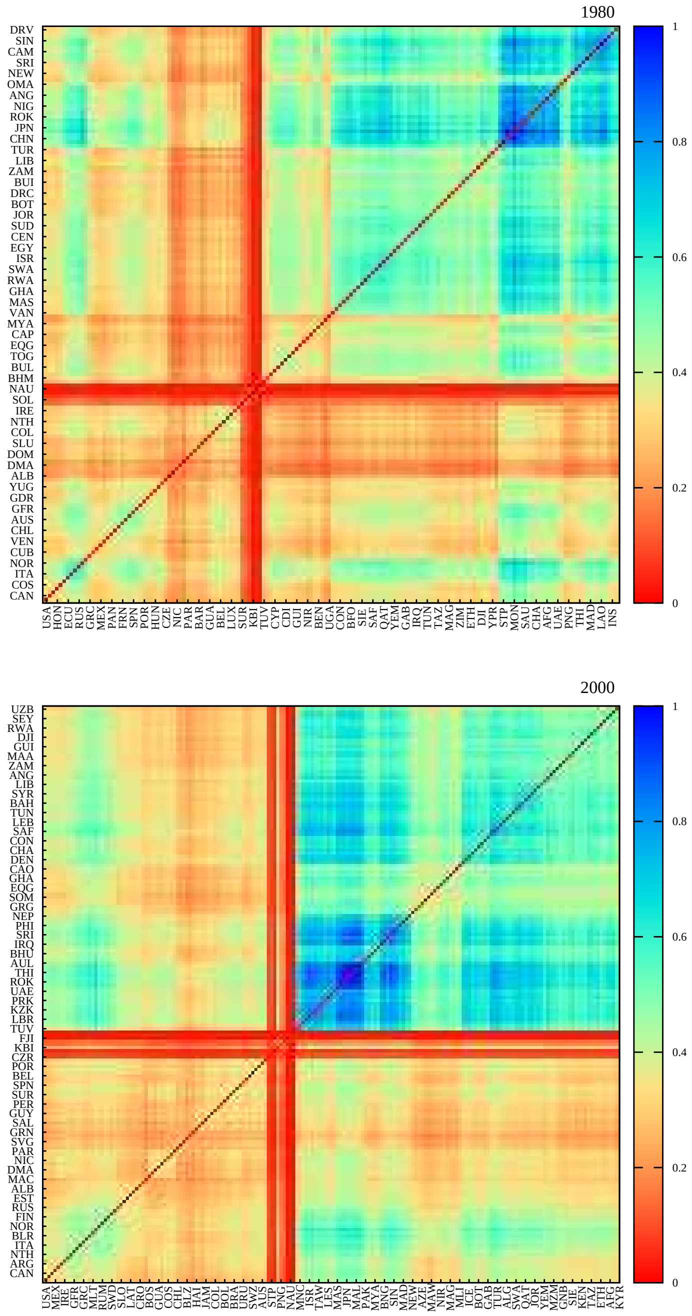

Figure 3: Heat map of co-ocurrences of nodes fired during the same cascade. The ordering of the nodes was performed with hierarchical clustering [9].

Still, as seen in Figure 1, the network rapidly synchronizes due to its locally coupled structure [8].

Finally, we present in Figure 3 a heat map with the co-occurrences of firings between nodes. That is, the relative number of times that two nodes have fired at the same cascade, i.e. the sensitivity of a node to fire signals that it receives from its neighbors. At top right part of both maps we identify East Asian countries (China, Japan, South Korea, Taiwan, Vietnam, Singapore, Thailand, Laos,...). These countries have a high dependence on exports and, in turn, are very dependent on them. This extreme regionalism was already seen in the Asian financial crisis of 1997. Other countries vulnerable to fluctuations in exports are the United Arab Emirates, Israel, Saudi Arabia and Madagascar. At bottom left we see developed economies like USA, Canada, Mexico and European countries.

Between 1980 and 2000, we detect on maps that there is an increase of areas with an homogeneous color. When international trade has grown enormously, this effect indicates that we have also established fixed trading partners of which we are forced to be more synchronized.

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